

**PATENT APPLICATION**

**PUMP SYSTEMS AND METHODS**

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## PUMP SYSTEM AND METHODS

### CROSS-REFERENCES TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Patent application Serial  
5 No. 08/899,785, filed July 24, 1997, which is a continuation-in-part of U.S. Patent  
application Serial No. 08/692,820, filed July 29, 1996, which is a continuation-in-part  
application of U.S. Patent application Serial No. 08/325,971, filed October 20, 1994, now  
U.S. Patent No. 5,505,258; PCT/US95/13290, filed October 19, 1995; and U.S.  
application Serial No. 08/610,630, filed March 4, 1996. All of these applications are  
10 incorporated herein by reference for all purposes.

### BACKGROUND OF THE INVENTION

#### Field of the Invention

The present invention is directed to a pumping system for producing well  
15 fluids from petroleum producing formations penetrated by a well. One aspect of the  
present invention includes the use of dual parallel tubing strings having the lower portions  
connected by a crossover flow connection, one of the tubing strings, i.e., the production  
tubing string, forming a flow path for flowing production fluids to the surface and the  
other, i.e., the power tubing string, for providing a conduit for inserting, operating and  
20 removing a rod-activated pump plunger used to lift well fluids from the well and to move  
the well fluids up the well to the surface through the crossover flow connection. A flow  
control valve for controlling production flow is also provided. A lubricating plunger is  
provided to direct fluid from the annulus between the power tubing and the rods to an  
area between the barrel of the pump and the lubricating plunger to increase the efficiency  
25 of the pump and to assist in sand control.

Another aspect of the invention relates to the management of course  
particulate, such as sand, that may tend to accumulate between the plunger and the pump  
barrel. More particularly, this aspect of the invention relates to techniques for preventing  
or greatly reducing the amount of course particulate that may accumulate between the  
30 plunger and the pump barrel.

## Description of Related Art

Pumping well fluids from wells penetrating producing formations has been done for many years. This is particularly true where heavy viscous oil must be moved to the surface. Often heavy viscous oils such as produced from California formations which are relatively close to the earth's surface contain sand and are difficult to pump. Steam and diluents have often been used to lower the viscosity of heavy crudes to improve flow and pumping efficiency; however, sand is still a major problem.

Heretofore dual tubing strings for a pumping system for producing petroleum have been suggested. For example, pumping installations utilizing parallel dual tubing strings are disclosed in U.S. Patents No. 4,056, 335 to Walter S. Secrest; 3,802,802 to F. Conrad Greer; and 3,167,019 to J.W. Harris.

There is still need, however, for a pumping system having dual production and power tubing strings which permit ease of operation which has movable parts including the pump plunger which may be removed from the power tubing string and replaced in the tubing string without the need for removing the tubing strings from the well, leaving only the pump barrel and tubing in place.

There is also a need for managing the location of coarse particulate, such as sand, that may exist in the fluids being pumped. Such techniques should be useful with pumping systems having both single and dual tubing strings.

## SUMMARY OF THE INVENTION

The present invention provides apparatus for producing well fluids from an oil bearing formation penetrated by a well including production tubing means forming a production flow path for production fluids between the earth's surface and a location in the well suitable for receiving well production fluids from a pump located in a parallel power tubing means. Flow control means are preferably located in the lower portion of the apparatus to permit flow of production fluids up the production flow path and to prevent flow of production fluids down the production flow path. Power tubing means extend down the well in parallel relationship with the production tubing means to a location in the well suitable for receiving production fluids into the lower portion of the power tubing means from said well. A tubing-type lubricating plunger is provided, and the plunger is preferably adapted to be inserted and removed from the power tubing means while the power tubing means are located in the well. A standing valve is provided to permit entry of well fluids from the producing formation into the

lower portion of the power tubing means. A crossover flow path is formed between the lower portion of the power tubing means and the flow path of the production tubing means for flowing production fluids out of the power tubing means and into the flow path of the production tubing means as the only flow path for transfer of production fluids to the earth's surface. Rod means for operating the tubing-type pump are operatively connected to the pump. Preferably, the means for operating the pump includes a rod string extending down the power tubing means and operably connected to the plunger of the insert or tubing-type pump. The operative elements of the insert or tubing-type pump are preferably located in the well below the location of the flow control means. The pump barrel of the tubing-type pump is a lowest section of the power tubing string. A valve is provided for flowing lubricating fluid from the power tubing string into a hollow pull tube connecting the lower end of the rod string to a lubricating plunger of the pump. The lubricating plunger has flow ports for permitting flow of lubricating fluid from inside the plunger to the annulus between the outside of the plunger and the inside of the pump barrel. The plunger is used in the tubing pump to receive fluids from the pull tube to lubricate the pump, to improve its efficiency and to control sand from entering the area of between the plunger and barrel.

In a more specific aspect the present invention provides apparatus for pumping petroleum from a well penetrating a petroleum producing formation which includes a downhole assembly located in a well at a position adapted to receive petroleum fluids from the well. The downhole assembly includes a parallel anchor having a first passage and a second passage formed parallel to the central axis of the parallel anchor. Means are provided for mounting the parallel anchor in the well at the desired position and a tubular connecting pup is connected to the first passage of the parallel anchor and extends down the well. A flow control means such as a standing valve, or a sliding valve, which permits flow up the connecting pup tubing and prevents flow down the connecting pup tubing is connected in the lower portion of the apparatus, for example, in or near the connecting pup. A crossover flow head is connected between the lower end of the connecting pup tubing below the standing valve and an opening in the pump barrel to provide a flow path for petroleum from the pump barrel through the standing valve into the lower portion of the connecting pup tubing. A production tubing string extends from the earth's surface down the well and is inserted into the first passage of the parallel anchor to form, in combination with the crossover flow head, the connecting pup tubing and a tubular string, a flow path to the earth's surface for petroleum. A power tubing

string is positioned in the well parallel to the production tubing string and extends through the second passage in the parallel anchor. Connecting means connect the lower end of the power tubing string to the upper end of the tubular landing nipple. A tubing-type seal off is inserted into the power tubing and landed in the tubular landing nipple. Means are provided to form a flow path for petroleum between the lower portion of the power tubing string and the lower portion of the production tubing string. Means are provided for disconnectably connecting the plunger of the tubing-type pump in operating position in the power tubing and the landing nipple for pumping fluid up the power tubing string to the flow path of the production tubing string. A lubricating plunger is provided for flowing lubricating fluid into the annulus formed between the pump barrel and a pump plunger.

The present invention provides an assembly which includes parallel power tubing and production tubing strings. A lubricating plunger is located inside and at the bottom of the power tubing string. The power tubing string connects to a bottom hole assembly with a crossover flow head which connects with the production tubing string. This provides for flow of production fluids from the pump to the production tubing string. A rod string, connected to a pumping unit at the surface gives the lubricating plunger of the tubing-type pump an up-and-down motion for pumping the well fluid to the surface through this production tubing string. A "Beard" valve is connected at the lower end of the rod string. The "Beard" valve includes a port to permit fluid flow from the power tubing annulus into the interior of the "Beard" valve. A hollow pull tube is connected to the lower end of the "Beard" valve and extends to and is connected to the lubricating plunger to provide for flow of lubricating fluids to the plunger. The plunger has ports for flowing the lubricating fluid out into the annulus between the plunger and the pump barrel. Thus, diluent or water with a surfactant may be placed in the power tubing for use in lubrication of the tubing pump to improve the efficiency thereof and to prevent sanding up of the pump.

The present invention utilized a tubing insert plunger. Thus, the plunger of the pump is connected to the rod string and is inserted inside the power tubing string. The lowermost section of the power tubing string forms the barrel of the pump. Generally, only the rod string has to be pulled to retrieve all moving and wearable pump parts except for the pump barrel. Thus, the apparatus of the present invention will save rig time when pump repairs or replacement is needed. Also because the production flow path is separated from the pumping rod string, the apparatus of the present invention will never

have a floating rod problem. It will also eliminate inertia bars and require smaller less expensive rods. In addition, lubricating fluid may be injected down the power tubing string through the "Beard" valve and the hollow pull tube rod and into a lubricating plunger of the pump. The lubricating plunger is provided with ports to direct the fluid coming from the hollow pull tube into the area between the plunger and pump barrel. Increasing the pressure in the annulus of the power tubing to exceed that of the production tubing keep sand out of the area between the plunger and pump barrel and to increase pump efficiency.

In one exemplary embodiment, the invention provides an apparatus for producing well fluids from an oil bearing formation penetrated by a well. The apparatus comprises a production tubing string which forms a production flow path for production fluids. The production tubing string is configured so that it may be positioned between the earth's surface and a location in the well suitable for receiving well production fluids. A power tubing string is also provided and includes an upper portion and a lower portion. The power tubing string extends down the well in a generally parallel relationship with the production tubing string to a location in the well suitable for receiving production fluids into the lower portion of the power tubing string. A pumping apparatus is disposed in the power tubing string to pump well fluids from the well into the lower portion of the power tubing string. Further, a crossover flow mechanism is provided between the lower portion of the power tubing string and the flow path of the production tubing string to divert the flow of production fluids out of the power tubing string and into the flow path of the production tubing string where it may be transferred to the earth's surface. A lubricant flow path is also provided and extends from the earth's surface to a location near the pumping mechanism to allow lubricants to be introduced into the pumping mechanism. In this way, lubricants may be provided to the pumping mechanism to substantially hinder undue wear that may be caused by sand or other coarse particulate found within the production fluids.

In one particular aspect, the production flow path has a smaller cross-sectional area than the lower portion of the power tubing string to increase the velocity of the production fluids when diverted into the production flow path. In this way, sand or other coarse particulate within the production fluids will remain suspended and will not tend to settle within the tubing strings to hinder operation of the apparatus.

Two different arrangements of the lubricant flow path may be provided to supply lubricant to the pumping mechanism. In one alternative, the lubricant flow path

may pass through substantially the entire length of the power tubing string. More specifically, the lubricant flow path may pass through the crossover flow mechanism. In this way, the overall size of the power tubing string may be reduced. In one particularly preferable implementation, the lubricant flow path will pass through at least one rod  
5 which extends through the power tubing string and which is used to operate the pumping mechanism.

In the second alternative, the lubricant flow path may be arranged to bypass the crossover flow mechanism. For instance, a side tubing string may be provided to bypass the crossover flow mechanism. The side tubing string will preferably have a  
10 bottom end which is connected to a lower portion of the power tubing string near the pumping mechanism so that the lubricant may be provided to the pumping mechanism.

With both the passthrough and bypass embodiments just described, a variety of pumping mechanisms may be employed. For example, the pumping mechanisms may comprise an insert pump, a progressive cavity pump, a tubing pump,  
15 and the like.

In another aspect, the invention provides techniques for managing course particulate, such as sand, within a pumping system. For example, in one embodiment, the invention provides a pumping system that comprises a pump barrel that is placed into a well casing. A plunger is reciprocatably positioned within the pump barrel and has an  
20 open top end, a bottom end, and a traveling valve at the bottom end. A connector is coupled to the plunger below the top end. Further, a rod is coupled to the connector and is translatable to reciprocate the plunger within the pump barrel using an upstroke and a downstroke. Upon each upstroke, the top end of the plunger directs particulate into the plunger and away from the pump barrel.

In one particular aspect, the plunger comprises a cylinder having an open top end that is inwardly tapered. Further, the connector is disposed within the cylinder. In this way, as the plunger is moved upward, the tapered top end funnels the particulate into the plunger and away from the pump barrel. In another aspect, the connector has at least one through hole to permit fluids to be moved upwardly through the connector and  
25 the plunger upon each downstroke of the plunger. In still another aspect, the pump barrel has a bottom end and a standing valve in the bottom end.

The invention also provides an exemplary method for pumping fluids from the ground. According to the method, a pumping system is placed into the ground and comprises a pump barrel and a plunger reciprocatably positioned within the pump barrel.

The plunger has an open top end, a bottom end, and a traveling valve at the bottom end. The system further includes a connector that is coupled to the plunger below the top end. With such a configuration, the plunger is reciprocated within the pump barrel with an upstroke and a downstroke, and particulate is directed into the plunger through the open top end and away from the pump barrel upon each upstroke.

In one aspect, the plunger comprises a cylinder having an inwardly tapered open top end to direct particulate into the cylinder upon each upstroke. In another aspect, the plunger has a traveling valve at the bottom end, and the pump barrel has a standing valve at a bottom end. In this way, fluids are drawn into the pump barrel through the standing valve upon each upstroke and are forced through the traveling valve upon each downstroke. In yet another aspect, the connector has a through hole such that fluids passing through the traveling valve move through the through hole and upwardly through the plunger.

#### OBJECTS OF THE INVENTION

A principal object of the present invention is to provide a pumping system having parallel power tubing and production tubing strings in which production is flowed up the production tubing through a flow control valve connected at the lower end of the pumping system. A rod operated insertable and removable pump plunger is disconnectably connected into the power tubing wherein the pump plunger may be removed from and inserted into the power tubing without the need to remove the tubing string from the well. A hollow pull tube is connected to the lower end of the rod string by a "Beard" valve and used to operate the pump plunger and also to provide a source of lubricating fluid for the lubricating plunger of the pump. The plunger has ports for flowing the fluid into the area between the pump barrel formed by the lower end of the power tubing and the outside of the plunger with increased pressure in the pump annulus to inhibit sand production and to increase pump efficiency. The increased pressure is accomplished by appropriate surface mechanism such as a pump.

Another object of the invention is to provide techniques for eliminating or greatly reducing the presence of coarse particulate between the pump barrel and the plunger. Additional objects and advantages of the present invention will become apparent to those skilled in the art from the drawings which are made a part of this specification and the detailed description of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagrammatic vertical sectional view of a well equipped with a pumping system assembled in accordance with the present invention;

Fig. 2 is an enlarged vertical sectional view of the portion of the system of Fig. 1 indicated by 100 in Fig. 1;

Fig. 3 is an enlarged vertical sectional view of the portion of the system of Fig. 1 indicated at 101 in Fig. 1; and

Fig. 4 is an enlarged vertical sectional view of the portion of the system of Fig. 3 indicated by 102 in Fig. 3; and

Fig. 5 is a sectional view take at A-A of Fig. 4.

Fig. 6 is a diagrammatic vertical sectional view of a pumping system having an insert pump and a lubricant flow path passing directly through a power tubing string according to the invention.

Fig. 6A is a cross-sectional view of a crossover flow head of the pumping system of Fig. 6.

Fig. 7 is a diagrammatic vertical sectional view of a pumping system having a tubing pump and a lubricant flow path passing directly through a power tubing string according to the invention.

Fig. 7A is a cross-sectional view of a crossover flow head of the pumping system of Fig. 7.

Fig. 8 is a diagrammatic vertical sectional view of a pumping system having a progressive cavity pump and a lubricant flow path passing directly through a power tubing string according to the invention.

Fig. 8A is a cross-sectional view of a crossover flow head of the pumping system of Fig. 8.

Fig. 9 is a diagrammatic vertical sectional view of a pumping system having an insert pump and a lubricant flow path which bypasses a crossover flow mechanism to supply a lubricant to a pump according to the invention.

Fig. 9A is a cross-sectional view of a stinger head of the pumping system of Fig. 9.

Fig. 9B is a cross-sectional view of a crossover flow head of the pumping system of Fig. 9.

Fig. 9C is a cross-sectional view of a fluid mixing head of the pumping system of Fig. 9.

Fig. 10 is diagrammatic vertical sectional view of a pumping system having a tubing pump and a lubricant flow path which bypasses a crossover flow mechanism according to the invention.

Fig. 10A is a cross-sectional view of a stinger head of the pumping system of Fig. 10.

Fig. 10B is a cross-sectional view of a crossover flow head of the pumping system of Fig. 10.

Fig. 10C is a cross-sectional view of a fluid mixing head of the pumping system of Fig. 10.

Fig. 11 is a diagrammatic vertical sectional view of a pumping system having a progressive cavity pump and a lubricant flow path which bypasses a crossover flow mechanism according to the invention.

Fig. 11A is a cross-sectional view of a stinger head of the pumping system of Fig. 11.

Fig. 11B is a cross-sectional view of a crossover flow head of the pumping system of Fig. 11.

Fig. 11C is a cross-sectional view of a fluid mixing head of the pumping system of Fig. 11.

Fig. 12 illustrates a down hole pump having a conventional plunger.

Fig. 13 illustrates one embodiment of a down hole pump having a plunger to direct the flow of coarse particulate away from a pump barrel according to the invention.

#### DESCRIPTION OF THE SPECIFIC EMBODIMENTS

Fig. 1 shows an overall sectional view of a pumping assembly in accordance with the present invention. A casing 10 is operably positioned in the well. Parallel power tubing 12 and production tubing 13 strings are positioned in the casing and connect with the bottom hole assembly which houses a down hole tubing pump and insert plunger 24 having lubricating ports 81-84 (see Figs. 4-5). The power tubing 12 and the production tubing 13 provide paths between the surface and a position in a well where well fluids are produced. As shown in Fig. 1, parallel anchor 15 has a first passage on the left and a second passage on the right of the anchor. A stab in tubing member 14 forming the bottom of the tubing string 13 extends through the first passage and is attached to the top of a connecting pup tubing 16 that screws into the top of a standing valve nipple 17.

A crossover flow head 19 attaches to the bottom of the standing valve nipple 17 on the left side. The right side of the crossover flow head 19 is attached to the bottom of a lock shoe landing nipple 18 and the top of sealing nipple 20. The power tubing string 12 passes down through the second passage in parallel anchor 15 on the right side and screws into the top of the lock shoe landing nipple 18. Beneath the cross-over flow head 19 is a sealing nipple 20. A pump barrel 21, which is preferably the lowermost section of the power tubing string, is provided below the sealing nipple 20. When the production tubing string 13 is installed, the power tubing string 12 and the bottom hole assembly are already made up together and in place down hole in the well at a suitable location for recovering well fluids.

The production tubing string 13 has attached to the bottom of it a stinger 14 with seals which then stabs into the passage provided in the left side of the parallel anchor 15. At the surface the production string 13 is connected to a conventional flow line which carries well fluids off to a production tank. A tubing-type insert plunger 24 having lubricating ports 81-84 is adapted to be inserted and removed from the power tubing. The lubricating plunger 24 has a hollow pull tube 25 that is connected to a rod string 22. The hollow pull tube 25 is connected to the rod string 22 by means of a "Beard" valve 26. The rod string 22 protrudes upward through the inside of the power tubing string 12 to the surface and is then hung off the bridle and horses head of a conventional pumping unit. The pumping unit gives the plunger 24 its up and down motion to pump the well fluids to the surface. The down hole seal off 28 is also sealed inside of the top lock shoe landing nipple 18 which holds the body or outside of the seal off 28 in place and allows only the plunger 24 to reciprocate up and down in the pump barrel 21 to pump the well fluids. The nipple 17 provides a flow control means in the production tubing flow path. Flow control means, such as a traveling valve or a sliding sleeve, are fully described in my earlier application Serial No. 08/325,971 and PCT/US95/13290, which have been incorporated by reference. A standing valve 29 at the lower end of the pump permits flow of well fluids into the lower portion of the pump barrel.

Referring again to Fig. 1 which shows the bottom hole assembly in more detail, the parallel anchor 15, with a stab in tubing member 14 having a sealing port for stabbing in, is attached to the top of the connecting pup 16 that screws into the top of the standing valve nipple 17. The cross-over flow head 19 attaches to the bottom of the standing valve nipple 17 on the left side. The right side of the cross-over flow head 19 is

attached to the bottom lock shoe landing nipple 18 and the top sealing nipple 20. The power tubing string 12 then passes down through the parallel anchor 15 on the right side and screws into the top of the top lock shoe landing nipple 18. Beneath the cross-over flow head 19 is a sealing nipple 20 which screws into the top of the pump barrel 21.

5 When the production tubing string 13 is installed, the power tubing string 12 and the bottom hole assembly are already made up together and in place down hole. The production tubing string 13 has attached to the bottom of it a stinger 14 with seals which then stabs into the left side of the parallel anchor 15.

Retrieving the bottom hole assembly from the well should never be  
10 necessary unless a hole develops in the power tubing string 12 from wear by the action of the rod string 22 or if there is sufficient wear of the pump barrel from the plunger 24. If this should happen, while the insert plunger is at the surface, simply pull the production tubing string 13, unsealing the stinger 14 with seals out of the parallel anchor 15. After this apparatus is at the surface, the bottom hole assembly may be pulled out with the  
15 power tubing string 12.

Fig. 2 is an enlarged sectional view of "Beard" valve 26 shown in Fig. 1 in the circle indicated by the number 100. The valve 26 is connected to the rod string 22. The "Beard" valve comprises a rod box 41 which is threadedly connected to an upper mandrel section 42 at its lower end. The mandrel section has a port 50 to permit flow of a  
20 lubricating fluid into the interior of the valve. A mating mandrel section 44 is threadedly connected to the upper mandrel section 42. A hollow pull tube 25 having an interior flow path 49 is connected to the lower mandrel 44 and to the top of the lubricating plunger 24. A check valve ball 43 and spring 47 which seats on seat 46 in mandrel section 44 and 42 permits flow of lubricating fluid downward through port 50 into pull tube 45 when  
25 pressure on the fluid in the power tubing is increased above the pressure in the pump barrel. The fluid flows to the lubricating plunger 24 inside of pump barrel 21.

Referring now to Fig. 3 which illustrates the lubricating plunger 24 and associated elements shown generally in the circle numbered 101 in Fig. 1. Fig. 3 is an enlarged vertical sectional view of the pump barrel 21 and the lubricating plunger 24.

30 Fig. 4 is a more greatly enlarged vertical section of the mid-portion of the plunger 24 at the circle 102 of Fig. 3, and Fig. 5 is a sectional view taken at A-A of Fig. 4.

In Fig. 3 the lubricating plunger 24 is illustrated in the downstroke portion of the pump cycle. Arrows, indicated generally as 90, show the flow of well fluids through the traveling valve, ball, seat, and cage indicated generally as 29 up the interior of

the plunger 24. As shown in Fig. 5, the well fluids pass through insert 92 in plunger connector 91 by means of ports 93-96. At the end of the downstroke and the beginning of the upstroke well fluids are raised up the production tubing as the traveling valve 29 closes.

5 Lubricating fluid 89 flows down hollow pull tube 25 to insert 92 in the plunger connector 91. The lubricating fluid then passes through ports 81, 82, 83 and 84 into the area between pump barrel 21-plunger 24 annulus indicated by the number 85 in Fig. 5. This lubricating fluid lubricates the plunger and pump barrel in annulus 85 to help prevent sanding of the pump. The lubricating fluid comes from the power tubing through  
10 the "Beard" valve into the hollow pull tube. The lubricating fluid is injected by means of increasing the pressure on the fluid in the power tubing to a pressure higher than the pressure in the annulus 85 plus pressure drop in the "Beard" valve and hollow pull tube.

Thus, the present invention provides apparatus for producing well fluids from an oil bearing formation penetrated by a well including production tubing means  
15 forming a production flow path for production fluids between the earth's surface and a location in the well suitable for receiving well production fluids from a pump located in a parallel power tubing means. Flow control means are located in the lower portion of the apparatus to permit flow of production fluids up the production flow path and to prevent flow of production fluids down the production flow path. Power tubing means are  
20 extended down the well in parallel relationship with the production tubing means to a location in the well suitable for receiving production fluids into the lower portion of the power tubing means from said well. A tubing-type plunger is provided and is adapted to be inserted and removed from the power tubing means while the power tubing means are located in the well. Means are provided for entry of well fluids from the well into the  
25 lower portion of the power tubing means for pumping therefrom. A crossover flow path is formed between the lower portion of the power tubing means and the flow path of the production tubing means for flowing production fluids out of the power tubing means and into the flow path of the production tubing means as the only flow path for transfer of production fluids to the earth's surface. Rod means for operating the tubing-type pump  
30 are operatively connected to the pump. Preferably, the means for operating the pump includes a rod string extending down the power tubing means and operably connected to the plunger of the tubing-type pump. The operative elements of the insert type pump are preferably located in the well below the location of the flow control means. A valve is provided for flowing lubricating fluid from the power tubing string into a hollow pull tube

connecting the lower end of the rod string to a lubricating plunger of the pump. The lubricating plunger has flow ports for permitting flow of lubricating fluid from inside the plunger to the annulus between the outside of the plunger and the inside of the pump barrel. The plunger is used in the tubing pump to receive fluids from the pull tube to lubricate the pump and to improve its efficiency and to control sand from entering the area of between the plunger and barrel.

Referring now to Figs. 6-8, three pumping system embodiments will be described which each have a lubricant flow path which passes directly through the power tubing string to introduce a lubricant to a pumping mechanism. In this way, the overall size of the pumping system may be reduced by allowing the lubricant to flow through an existing tubing string.

Referring first to Fig. 6, a pumping system 200 having an insert pump 202 will be described. Pumping system 200 comprises a casing 204 having a pair of vents 206, 208 and a plurality of perforations 210 (or liner slots) which allow production fluids to pass through casing 204. Casing 204 further includes a flange 212 is secured to a dual well head flange 214 to hold a power tubing string 216 and a production tubing string 218 within the well. Production tubing string 218 defines a flow path 220 as indicated by the arrows. Power tubing string 216 includes an upper portion 222 and a lower portion 224. Lower portion 224 includes insert pump 202.

Connecting power tubing string 216 to production tubing string 218 is a crossover flow head 226 (see also Fig. 6A). Conveniently, a tubing release 232 is provided to connect production tubing string 218 to crossover flow head 226. As illustrated in Fig. 6A, the crossover flow head includes a power tubing string portion 228 and a production tubing string portion 230. Portion 230 has a smaller cross-sectional area than portion 228 so that when production fluids are diverted from portion 228 and into portion 230, the rate of flow of the production fluid will increase. In this way, sand or other coarse particulate within the production fluids will remain generally suspended until exiting production tubing string 218 above the earth's surface.

Extending through power tubing string 216 is a rod 234. Rod 234 is preferably constructed to be solid and passes through a stuffing box 236 as is known in the art. Solid rod 234 is connected to a hollow rod 238 by a check valve 240. In turn, hollow rod 238 is employed to operate insert pump 202.

Insert pump 202 comprises a plunger 242 which moves in an up and down motion as dictated by hollow rod 238. Operably attached to hollow rod 238 is a ring

traveling valve 244 and a ring standing valve 246. Conveniently, friction rings 248 are provided to form a seal between the pump barrel below plunger 242 and power tubing string 216. A sealing unit 250 is further provided to prevent production fluids from traveling up power tubing string 216 as described in greater detail hereinafter.

5           Upon upstroke of hollow rod 238, plunger 242 is lifted to create a vacuum within the pump barrel below plunger 242. In turn, ring standing valve 246 is lifted by this vacuum to allow production fluids to enter into lower portion of pump barrel below plunger 242 as indicated by arrow 252. Upon downstroke of the plunger 242, positive pressure is created within lower portion of the pump barrel below plunger 242, causing  
10   ring standing valve 246 to close and causing ring traveling valve 244 to unseat. In turn, the production fluids within lower portion of the pump barrel below plunger 242 pass through plunger 242 and into crossover flow head 226 as illustrated by arrows 254. At this point, sealing unit 250 prevents the production fluids from passing further through power tubing string 216. Hence, the production fluids cross over from portion 228 and  
15   into portion 230, where they travel through production tubing string 218 until they exit above the earth's surface.

          To provide a lubricant and/or a diluent to appropriate locations, the lubricant or diluent may be input into power tubing string 216 through a port 256. As indicated by arrows 258, the lubricant will lubricate between the up and down motion of  
20   rods 234 and the stationary power tuber string 216. The lubricant will then pass through a hole 260 in check valve 240 if the lubricant is under sufficient pressure to unseat spring valve 262. The lubricant then passes through hollow rod 238 as shown. During its travel, the lubricant may exit hollow rod 238 in the middle of plunger 242 as shown to lubricate the surfaces between plunger 242 and pump barrel 201. Some of the lubricant will  
25   continue its path through hollow rod 238 until exiting through a plurality of orifices 264. In this manner, the lubricant will also serve as a wetting agent to water wet all metal surfaces in pump 202 to in flowing production fluids into power tubing string 216 as indicated by arrows 266. In the same manner (using diluent), the diluent will reduce the viscosity of the production fluids assisting in the flowing of production fluids into the  
30   power tubing string 216 as indicated by arrows 266.

          Hence, by constructing rod 238 to be hollow, a lubricant and/or diluent may be passed directly through power tubing string 216 into hollow rod 238 to supply a lubricant/diluent to plunger 242 and to supply a lubricant/diluent to the production fluid to assist in removing the production fluid from the well. By passing rod 238 directly

through power tubing string 216, the outer diameter of pumping system 200 may be reduced, while still providing an effective way to supply the lubricant/diluent to the suction of the pump. As illustrated by arrow 268, sufficient space is also provided between casing 204 and strings 216 and 218 to allow free gas to escape from the well.

Another particular advantage of pumping system 200 is that insert pump 202 may be pulled from power tubing string 216 while power tubing string 216 remains in the well. In this way, insert pump 202 may conveniently be repaired or replaced without having to pull any tubing strings as described with previous embodiments.

Shown in Figs. 7 and 7A is a pumping system 270 which is similar to pumping system 200 of Fig. 6 except that pumping system 270 includes a tubing pump 272. Pumping system 270 comprises a casing 274 having vents 276 and 278. A plurality of perforations 280 are provided in casing 274 to allow production fluids to pass into casing 274. A casing flange 282 is attached to a dual well head flange 284 to hold the two tubing strings 286, 288 in place.

Disposed within casing 274 is a power tubing string 286 and a production tubing string 288. A crossover flow head 290 connects production tubing string 288 to power tubing string 286. Conveniently, a tubing release 292 is provided to allow production tubing string 288 to be attached to crossover flow head 290. Crossover flow head 290 includes a power tubing string portion 294 and a production tubing string portion 296 which allow production fluids passing upwardly through power tubing section 286 to be diverted into production tubing string 288 in a manner similar to that previously described with other embodiments.

Passing through power tubing section 286 is a solid rod 298 which is moved up and down to operate tubing pump 272 as described in greater detail hereinafter. Conveniently, an on/off tool 300 is provided to allow convenient removal of solid rod 298. A tubing drain 302 is provided to allow fluids to be drained from the system during disassembly as is known in the art.

A hollow rod 304 is attached to solid rod 298 via a check valve 306. Further down power tubing string 286, hollow rod 304 is connected to a plunger 308 which is part of tubing pump 272. Tubing pump 272 further comprises a tubing pump barrel 310, a traveling valve 312 and a standing valve 314. Further, a sealing unit 316 is provided to prevent the flow of production fluids upwardly through power tubing string 286 so that the flow may be diverted into production tubing string 288. During operation, hollow rod 304 is lifted to lift plunger 308. This action causes a vacuum within tubing

pump barrel 310, causing standing valve 314 to lift and production fluids to enter into tubing pump barrel 310 as indicated by arrows 318. Upon downstroke of rod 304, standing valve 314 is seated while traveling valve 312 is lifted to allow the production fluids within tubing pump barrel 310 to pass through plunger 308 and into crossover flow head 290. As illustrated by arrows 320, the production fluids are then diverted into production tubing string 288 where they will exit above the earth's surface. Free gases may travel around production tubing string 286 as indicated by arrow 322.

A port 324 is provided to allow a lubricant or diluent to be introduced into power tubing string 286 as indicated by arrows 326. The introduced lubricant passes through a hole 328 in check valve 306. When the introduced lubricant is at a sufficient pressure, spring valve 330 will release to allow the lubricant to pass through hollow rod 304 as shown. The lubricant will then exit hollow rod 304 in the middle of plunger 308 as shown by the arrows. Additional lubricant may pass through the entire length of hollow rod 304 where it will exit through apertures 332 as shown. In this way, the lubricant or diluent may be supplied to the production fluids to assist in their removal from the well. Further, the lubricant introduced near plunger 308 will provide the necessary lubricant in order to lubricate tubing pump 272.

Referring now to Figs. 8 and 8A, another embodiment of a pumping system 340 will be described. Pumping system 340 is similar to pumping system 270 of Fig. 7 except that pumping system 340 employs a progressive cavity pump 342. For convenience of discussion, the elements of pumping system 340 which are similar to those in pumping system 270 will be referred to with identical reference numerals.

Progressive cavity pump 342 comprises a hollow rotor 344 which is connected to hollow rod 304. Hollow rotor 344 in turn is attached to a stator 346. In this way, when rotor 344 is rotated by rod 304, stator 346 will draw production fluids from the well, into power tubing string 286 and into crossover flow head 290. In crossover flow head 290, the production fluid is diverted from portion 294 to portion 296 to allow production fluids to be passed through production tubing string 288 as previously described. Hollow rotor 344 is connected to a passthrough stinger rod 348 having orifices 332. In this way, a lubricant or diluent may be introduced into port 324 where it will pass through check valve 306 in a manner similar to that previously described with system 270. The lubricant or diluent will then pass through orifices 332 and will be drawn into the suction of the pump 342 in power tubing string 286. The diluent will serve to dilute

the production fluids to assist in their removal from the well, while the lubricant will lubricate the rotor and stator to enhance operation of progressive cavity pump 342.

Figs. 9, 10 and 11 show respective alternative embodiments of the pumping systems of Figs. 6, 7 and 8. The embodiments in Figs. 9-11 differ in that the lubricant or diluent passes from the power tubing string through a stinger head, around the crossover flow head, and down to a fluid mixing head at the suction of the pump. In this way, the need for hollow rods is eliminated since the lubricant is passed around the cross over flow head.

Referring now to Figs. 9-9C, another embodiment of a pumping system 350 will be described. For convenience of discussion, pumping system 350 will be described using similar reference numerals to describe pumping system 200 of Fig. 6 with the addition of a '. Pumping system 350 differs from pumping system 200 in that pumping system 350 includes a side tubing string 352 which allows a lubricant 258' to bypass portion 228' of crossover head 226'. A stinger head 354 (see Fig. 9A) allows for the diversion of the lubricant from power tubing string 216' and into side tubing string 352 as shown. Sealing unit 250' prevents the flow of lubricant further down power tubing string 216'.

As best illustrated in Fig. 9A, a crossover fluid path 356 is provided to allow the lubricant to pass from power tubing string 216' and into side tubing string 352. A check valve 358 is provided in side tubing string 352 to regulate the flow of lubricant through side tubing string 352. In particular, check valve 358 includes a spring which allows the valve to open when a sufficient pressure is applied by the lubricant. After passing through check valve 358, the lubricant passes through an adjustable union 360 and through a lumen 362 in crossover flow head 226' (see Fig. 9B). The lubricant continues through side tubing string 352 and into a fluid mixing head 364 (see Fig. 9C). In fluid mixing head 364, the lubricant is channeled into power tubing string 216' in the vicinity of insert pump 202' suction. In this way, when insert pump 202' is operated, sufficient lubricant will be provided. In operation, plunger 242', traveling valve 244' and standing valve 246' operate similar to related elements in insert pump 202 of Fig. 6 to pump production fluids from the well as indicated by arrows 366.

Referring now to Figs. 10-10C, a further embodiment of a pumping system 370 will be described. For convenience of discussion, pumping system 370 will be described using similar reference numerals to those used previously in describing pumping system 270 of Fig. 7 followed by a '. Pumping system 370 differs from

pumping system 270 of Fig. 7 in that pumping system 370 includes a side tubing string 372 to bypass a lubricant around cross over flow head 290'. A stinger head 374 (see Fig. 10A) is provided to divert the flow of the lubricant as indicated by arrows 326' into side tubing string 372. A check valve 376 is provided within side tubing string 372 to regulate the flow of lubricant through side tubing string 372 similar to valve 358 of Fig. 9. As best shown in Fig. 10B, crossover flow head 290' includes a lumen 378 through which side tubing string 372 passes. An adjustable union 380 is also provided in side tubing string 372. A fluid mixing head 382 is provided to divert the flow of lubricant from side tubing string 372 and back into power tubing string 286' as shown. In this way, a lubricant will be provided to lubricate tubing pump 270'. Tubing pump 270' includes a plunger 308', a traveling valve 312' and a standing valve 314' which operate to pump production fluids from the well and up through power tubing string 286' similar to the embodiment in Fig. 7. Further, crossover flow head 290' diverts the flow of the production fluid from portion 294' to portion 296' where it will pass through production tubing string 288' similar to the embodiment of Fig. 7.

Referring now to Figs. 11-11C, still yet another embodiment of a pumping system 390 will be described. Pumping system 390 is similar to pumping system 340 of Fig. 8 except that the lubricant is bypassed around a portion of the power tubing string. For convenience of discussion, similar elements will employ the use of similar reference numerals followed by a '.

Pumping system 390 differs from pumping system 340 in that the lubricant bypasses a portion of power tubing string 286' through a side tubing string 392. In particular, a stinger head 394 (see Fig. 11A) in combination with sealing unit 316' diverts the flow of lubricant from power tubing string 286' and into side tubing string 392 as illustrated by arrows 326'. A lubricant then passes through a check valve 396 similar to check valve 376 of Fig. 10 which regulates the flow of lubricant through side tubing string 392. A lumen 398 is provided within crossover flow head 290' to allow side tubing string 392 to pass through crossover flow head 290'. An adjustable union 400 is also provided in side tubing string 392. Finally, a fluid mixing head 402 (see Fig. 11C) is provided to divert the flow of lubricant from side tubing string 392 back into power tubing string 286' in the vicinity of progressive cavity pump 342' suction. In this way, progressive cavity pump 342' will receive sufficient lubrication for operation.

Upon rotation of rod 298', rotor 344' is rotated inside stator 346'. In turn, this causes production fluids within the well to be drawn up into the lower portion of

power tubing string 286'. The production fluids will then be diverted into production tubing string 288' in a manner similar to that previously described.

Another feature of the invention is the ability to direct or funnel coarse particulate, such as sand, away from the interface between the plunger and pump barrel.

5 In this way, the life of the pump is increased by reducing the wear between the plunger and the barrel. The techniques of the invention may be used with pumping systems employing a single tubing string, or multiple tubing strings, including the dual-string pumping systems described herein.

10 An example of problems that may be created when sand or other coarse particulate is present in the fluid being pumped is illustrated in Fig. 12. Shown in Fig. 12 is a conventional down hole pump 500. Pump 500 comprised a pump barrel 502 that is adapted to be placed within a casing as is known in the art. Pump barrel 502 is cylindrical in geometry and has a bottom end 504 where a standing valve 506 is disposed. The opposite end of pump barrel 502 extends to the ground surface as is known in the art. Slideable within pump barrel 502 is a plunger 508 having a top end 510, a bottom end 512, and a cylindrical center section 514. Disposed in bottom end 512 is a traveling valve 516. Coupled on top of top end 510 is a connector 518. Extending from connector 518 is a rod 520. In this way, plunger 508 may be reciprocated in an up and down motion by reciprocating rod 520. Connector 518 includes a pair of through holes 522 to permit fluids to be evacuated from plunger 508.

15 In operation, rod 520 is translated downward to slide plunger 508 further into pump barrel 502 (referred to as the downstroke). In so doing, standing valve 506 is forced closed and traveling valve 516 is forced open due to the presence of a fluid within pump barrel 502. The fluid entering plunger 508 passes upward through through holes 25 522 where it may be evacuated from the pump. Rod 520 is then moved upward (referred to as the upstroke) to close traveling valve 516 and to open standing valve 506. Due to the vacuum created within pump barrel 502, fluids from the well are drawn into pump barrel 502. On the next downstroke, the process is repeated to pump additional fluids out of the well.

30 As shown, the top end of connector 518 is tapered downward from the center at approximately a 45° angle. As also shown, connector 518 has a slightly smaller outer diameter than that of plunger 508. For example, connector 518 may have an outer diameter that is 1/60,000 of an inch smaller than the outer diameter of plunger 508. Because of such a configuration, sand tends to accumulate between connector 518 and

pump barrel 502 upon reciprocation of the plunger as illustrated by the arrows. On further operation, the accumulated sand or other coarse particulate will find its way between pump barrel 502 and plunger 508. As such, significant problems may occur with the pump, including stuck plungers, gaulded plungers and barrels, reduced pump efficiency, and shortened pump life.

The invention provides techniques for preventing or greatly reducing the amount of accumulated sand at the top of the plunger to prevent the sand from being deposited between the plunger and pump barrel. This may be accomplished, for example, by moving the connector from the top of the plunger so that it is deposited within the plunger. In this way, coarse particulate will not tend to accumulate at the top of the plunger. Further, the wall of the plunger may be inwardly tapered so that the plunger acts as a scraper on the upstroke to scrape the coarse particulate from the walls of the pump barrel.

One example of such a down hole pump 524 is illustrated in Fig. 13.

Pump 524 comprises a pump barrel 526 having a standing valve 528 that may be constructed similar to analogous components in down hole pump 500. Translatable within pump barrel 526 is a plunger 530 and has an open top end 532, a bottom end 534 and a cylindrical section 536. As shown, top end 532 is tapered inwardly so that top end 532 forms a sharpened edge. Coupled to plunger 530 near bottom end 534 is a connector 538 that has a pair of through holes 540. Conveniently, connector 538 may be coupled to cylindrical section 536 so that it is spaced apart from a traveling valve 542 in bottom end 534. A rod 544 is coupled to connector 538 to reciprocate plunger 530 in an up and down motion. A pumping unit that is disposed above ground is coupled to rod 544 to translate rod 544 as is known in the art.

On the downstroke of plunger 530, standing valve 528 closes and traveling valve 542 opens to permit fluid to pass through through holes 540 and upwardly through plunger 530. Upon the upstroke of plunger 530, traveling valve 542 closes and standing valve 528 opens in a manner similar to that previously described with pump 500. Because connector 538 is disposed within plunger 530, it does not assist in accumulating sand or other coarse particulate at top end 532 of plunger 530. Instead, the open top end 532 serves to direct or funnel sand or coarse particulate into the interior of plunger 530 and away from the pump barrel wall as illustrated by the arrows. Further, upon the down stroke of plunger 530, fluid that is moved upwardly through the plunger catches the coarse particulate and moves it upward without causing any damage to the pump.

Moreover, the sharpened edge at top end 532 serves to scrape and clean the walls of pump barrel 526 upon each upstroke. In this way, the chances for having sand or other coarse particulate accumulate between plunger 530 and pump barrel 526 are eliminated or greatly reduced.

Hence, by moving connector 538 within plunger 530, the wear between plunger 530 and pump barrel 536 may be greatly reduced, thereby prolonging the life of the pump. Further, by constructing pump 524 in this manner, a tighter fit may be provided between plunger 530 and pump barrel 526 without experiencing gaulding. Further, a higher pump efficiency may be achieved along with additional production of fluids. As another advantage, such a pump may use a pump off controller with a sandy well. By reducing the amount of sand between plunger 530 and pump barrel 526, less well pulling is also required. As such, lower operating costs may be achieved resulting in higher profits.

Another example of how coarse particulate may be managed to prevent its accumulation between the plunger and the pump barrel is illustrated with the pumping assembly of Fig. 3. As shown, plunger 24 has a inwardly tapered top end that forms a sharpened edge similar to the plunger of Fig. 13 as just described. Further, the connector between pull tube 25 and plunger 24 is placed downwardly within plunger 24. In this way, on the upstroke of plunger 24, sand or other coarse particulate is funneled away from the walls of pump barrel 21 in a manner similar to that previously described in connection with Fig. 13.

As another example, plunger 242 of pumping system 200 of Fig. 6 has an open top end that is inwardly tapered. Rod 238 is coupled to plunger 242 within the plunger at a location that is below the open top end. In this way, sand or other coarse particulate is funneled into plunger 242 rather than accumulating at the top end of plunger 242 in a manner similar to that described with previous embodiments.

A similar construction is found with pumping system 270 of Fig. 7. As shown, plunger 308 has an open top end that is inwardly tapered. Rod 304 is coupled to plunger 308 within the interior of the plunger and below the open top end to permit sand and other coarse particulate to be funneled into the plunger in a manner similar to that described with previous embodiments.

The principles, preferred embodiments and modes of operation of the present invention have been described in the foregoing specification. However, the invention which is intended to be protected is not to be construed as limited to the

particular embodiments disclosed. The embodiments are to be construed as illustrative rather than restrictive. Variations and changes may be made by others without departing from the spirit of the present invention. Accordingly, all such variations and changes which fall within the spirit and scope of the present invention is defined in the following

5 claims are expressly intended to be embraced thereby.